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All communications should be addressed to the Editor.

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Notices of the Royal Aëronautical Society.

New Members.

The following have been elected members of the Society in the various grades:—

Fellows.—Dr. W. F. Durand, Lieut.-Colonel J. C. Porte, M. A. S. Riach, Sir Robert Hadfield (5).

Associate Fellows.—E. J. H. Lynam, Capt. G. S. Walpole, Capt. A. A. Ross, H. A. Webb, C. F. Chambers, E. F. W. Koolhoven, A. J. T. Ireland, T. S. Letcher, D. Stevenson (9).

Members.—A. M. Bourke, W. Fenton, J. Lord, J. H. Lowther, H. C. Sturgeon, W. de L. Goslett, F. E. Oxley, F. O. S. Leak, S. Squire, H. F. Goode, W. A. Sedgrove, J. H. Woodruff, H. S. Brown, H. S. Fairhurst, J. E. Pearce (15).

Associate Members.—L. J. Parrish, A. H. Clarke, F. Thomas, J. E. Bearder, F. Jones, J. A. Currie, S. T. Green, E. F. R. Catterall, T. Buckley, H. Blackman (10).

Students.—G. M. Bryer, W. I. Rendall, J. W. Gossage, W. Kennedy, T. Wrigley, F. W. Bourne, S. W. Rendall, A. Hampson, E. Sipt, W. Gregg, H. E. Taylor, T. F. Davey, J. Skidmore, H. Warburton, C. E. Fielding.

Foreign Member.—H. Whittinghame.

The New Session.

The new Session of the Society will begin in October. Members desiring to offer communications are requested to advise the Secretary at as early a date as possible so that the arrangements may be well in hand before autumn.

THE SIXTH "WILBUR WRIGHT" LECTURE.

The sixth "Wilbur Wright" lecture was given in the Central Hall, Westminster, on Tuesday, June 25th, at 7.30. There was a very large attendance and among those present were:—Sir Horace Darwin (Chairman, Air Inventions Committee), Major Baird (Under-Secretary to the Air Ministry), the French Ambassador, the Italian Ambassador, the Secretary to the American Embassy, the High Commissioner for Canada, the High Commissioner for South Africa, the High Commissioner for New Zealand, Colonel Sir F. Hall, Mr. Joynson-Hicks, M.P. (Chairman, Parliamentary Air Committee), Mr. H. White Smith (Chairman, Society of British Aircraft Constructors), Lord Ferrers, Colonel J. Ward, M.P., Sir Herbert Neild, M.P., Mr. Griffith Brewer, Mr. Noel Smith, the Right Hon. H. A. L. Fisher, M.P., Sir Fortescue Flannery, M.P., the Chinese Minister, General Colvin, M.P., Lord Cottesloe, the Presidents of the Institution of Civil, Electrical and Mechanical Engineers, the President of the Institution of Naval Architects, General Ellington, Lord Balfour of Burleigh, the Belgian Minister, Sir Herbert Austin, Lord Aberconway, Lord D'Abernon, the Columbian Minister, Sir Napier Shaw, Sir R. T. Glazebrook, General Alexander, Lord Montagu of Beaulieu, Lord Foley, General F. H. Sykes, the Chilian Minister, Sir James Frazer, the Right Hon. Wm. Brace, M.P., the Japanese Ambassador, Lord Saltoun, Lord Russell, Lord Muir Mackenzie, General Maitland, Sir David Prain, C.I.E., Mr. J. W. Gulland, Mr. Clement Edwards, M.P., Sir Henry Norman, M.P., Sir Shirley Murphy, Lord Erskine, Sir Alex. Kennedy, Mr. L. Haslam, M.P.

Major-General Ruck, the Chairman of the Society, formally welcomed Sir William Weir, Secretary of State to the Air Ministry, and assured him what very great pleasure it gave to the Council and members of the Society to see him occupying the chair that night.

Sir William Weir then took the chair.

The CHAIRMAN said that in many ways it was a rare and genuine honour to preside at the meeting. Firstly, because of his interest in everything connected with the problems of the air—an interest founded not only on his own personal tastes and inclinations, but stimulated by the office with which he was associated.

Secondly, it was a privilege for all of them to pay homage by their presence to the memory of a very great American citizen and of a very great pioneer in flying—Wilbur Wright. Wilbur Wright now took his place on the roll of fame along with Fulton, Stephenson, and Bell, as one of those whose discoveries had marked a milestone in the progress of the science of transport in one or other of the three elements.

A third reason why he was glad to be there was that it enabled him to express that recognition which he felt to be due, if not overdue, to the work of the Aëronautical Society. The Society was by far the oldest aeronautical society in the world. It was founded as far back as the year 1866 and had had to struggle against many vicissitudes and a considerable degree of ridicule before it had reached its present honourable and successful position. Before the war the Society had made every effort to awaken public opinion to the importance of flying, both to the army and to the navy, and he could say now, from his own personal experience and knowledge, that during the war the members of the Society had endeavoured in every way, and most successfully, to help the Government in developing the progress and strengthening the efficiency of the Air Forces. It was with peculiar pleasure that, with the gracious permission of the King, he was able to announce that His Majesty had been pleased to allow the Society to

be known in the future as the Royal Aëronautical Society. His Majesty had thus given a striking recognition of the importance of the work which the Society had performed, and which he trusted it would continue to perform, in the interests of the nation.

The Home Secretary had asked him to hand over to their Chairman the following letter:—

> "To Major-General Ruck. I am directed by the Secretary of State to inform you that he has had the honour to lay before the King your application, transmitted to this Department through Major Baird, for permission to use the prefix 'Royal' in the name of the Aëronautical Society, and that His Majesty has been graciously pleased to command that the Society shall henceforth be known as The Royal Aëronautical Society."

He was sure they would all unite in welcoming the lecturer of the evening, Dr. Durand, as representative of our great ally, the United States of America. Dr. Durand was the Chairman of the American Advisory Committee for Aeronautics, a body which had played a very great part in the development of aeronautical construction in the United States during this war. His great qualifications as a scientist were well known to all of them, and it was unnecessary for him to enlarge upon them, or to intervene in any way between the audience and his lecture. At the same time, they would perhaps pardon a single personal note. His first association with Dr. Durand was one of which he (Dr. Durand) was not perhaps himself aware. He remembered very well as a schoolboy writing down from his father's dictation a paper on an engineering subject for a very large Engineering Congress held in Chicago, he believed in 1896, and addressing that paper to Dr. Durand, who was Secretary and Editor to the Congress. He desired, on their behalf, to offer their most cordial welcome to Dr. Durand, and to invite him now to give them his lecture on "Some Outstanding Problems in Aeronautics."

Dr. W. F. DURAND then gave his lecture on "Some Outstanding Problems in Aeronautics."

On the conclusion of the lecture,

Sir WILLIAM WEIR, in moving a vote of thanks to the lecturer, said that Dr. Durand had dealt in his most admirable paper with the main problems which now confronted the designer and the constructor of aeroplanes. The clearly reasoned exposition which he had given of modern tendencies, together with difficulties in design, and the suggestions which he had made for the solution of the latter, would no doubt be carefully studied by all the technical members of the Society and all those now engaged on the application of aeronautical science to manufacture. But as he had listened to the paper he had formed this impression very clearly—that if it were possible for all the designers, and all those interested in aeronautical problems whom he saw in that hall, to discuss the paper fully and freely, apart from the limitation of war exigencies, what a revelation it would form of the progress made in the last three years! He desired, if he might, in that connection to pay a very much merited tribute to the skill, the ingenuity, and the technical capacity of the aircraft designers of Great Britain.

Without going back to the early days of recrimination, which he understood was characteristic of all discussion, involving the Royal Aircraft Factory, for example, he wished to point out that the work done there had laid the firm and solid basis for design on which most of to-day's best work was founded. No one realised that more clearly than the present trade designers. But the new policy of entrusting design—pure design—to the industry itself had been, he thought, very successful, and the country owed a very deep debt of gratitude to those firms who were devoting so much study and skill to the development of our designs. And in saying this he would refer even more particularly to those

pioneer firms who had worked for so many years without any particular prospect of reward in any shape or form. While the exigencies of war time prevented the publication of records of technical progress, he would say that great as had been the progress in the last three years of the war, the past year had marked an even greater advance. The rate of advance was being accelerated. The scientists, the designers, the engineers of this country, had played an outstanding part in that progress, and their combined achievement was one that they might very well be proud of. He thought he could define our technical position in relation to that of the enemy by saying that our technical superiority at the present time was measured—was equalled—by the superiority in the human qualities of skill, enterprise, and endurance displayed by our pilots.

In that connection it might perhaps interest them to hear a report which he had received last night from General Salmond regarding a pilot, a Squadron Commander, who had been taken away from the front for other duties at home. He had not been particularly pleased at being withdrawn from France, and this was the record of his morning's work before he left:—

> "Major ——— left the aerodrome at 9.40 a.m., when the rain had ceased for a time. He met five Pfalz scouts and a two-seater east of Plug Street at 9.58 a.m. He shot down two of the scouts, which crashed definitely, chased two more so that they collided, and both broke up and crashed. He then attacked the two-seater and shot it down in flames. The fifth scout escaped. He then returned to the aerodrome and left for England at 11 o'clock in the morning."

He had given them what he believed to be a clear and true indication of the technical position at the present time, but it must not be forgotten that progress and development were so rapid that they would never be content with their existing state, or place undue confidence in the results of their own future efforts. But to-day they had the solid foundation of the full and whole-hearted co-operation of the United States upon which to rest their trust for the future. In this bitter struggle—which they had firmly believed from the beginning to be in defence of the very foundations of our civilisation—apart from the great material advantages she could afford, the knowledge that the United States was united with us in sympathy and faith had stimulated and enheartened us from the day that she had declared war. Since then we had watched with ever-growing admiration and gratitude the mobilisation of her very large resources, with the skill and energy which were the concomitant of American enterprise. In every field of warfare we were receiving her whole-hearted assistance. In the field of air warfare, the assistance which America had already rendered to us in the way of personnel was very great. The records of her pilots had already appeared in the Press, and he might say that the American officers and men who were now being trained, both in this country and in France, had won golden opinions from all with whom they had come in contact. The universal opinion was that no praise could be too great for their energy and their capacity, for their willingness to learn, their desire to co-operate in everything. Therefore, so far as men were concerned, they could have the fullest confidence in the future success of the American Air Force.

With regard to material, he thought they might now begin to speak with equal confidence. The tests which had recently been applied, in France and this country—very thorough and searching tests—to the Liberty engine, justified, he hoped, the prediction that it would prove a most valuable contribution to the allied resources, and that the United States could go ahead and push these productions with every confidence. The results of the experience so far obtained placed the engine in the very first line of high-powered aero motors. It was well understood, he believed, that some criticism should be directed against the slow rate of production of these motors during the last three or four months. But he would like to point out that a considerable interval must, and always would, exist between

the experimental and the commercial production of any new aero motor. No engine, even of the best design, and in the country with the greatest resources and facilities, could escape the period of what was called teething troubles before the motor was anything like fit for use in the field on any large scale. The Liberty engine, accordingly, was an example of what the allies might expect in the matter of aircraft production from the scientists and designers of America, of whom Dr. Durand stood there among them as representative. The various methods of the utilisation of aircraft in warfare were growing very rapidly—so rapidly that it was now perfectly clear that even with all the help America could give, the fullest demand which could be made to fulfil all the different functions for which aircraft were suitable in war time could never be met in this war. More aircraft, with their men and personnel, would always be required than could possibly be supplied—the functions were growing so rapidly. To achieve the best allocation would involve a policy of concentration, and in this the allies were counting on all the help in machines and men that the United States could give. Dr. Durand, by his lecture, had himself shown cause for placing every trust in the intellectual capacity and technical skill of the men upon whom America depended for the development of her aircraft. He knew that he was expressing the wish of all present in moving a very hearty vote of thanks indeed to Dr. Durand for the honour which he had done the Royal Aëronautical Society in delivering before it so important and so illuminating and address.

Dr. DURAND, in acknowledging the vote of thanks, said that with regard to the co-operation of the United States in the great enterprise in which, with the alliès, they were now engaged, he wished to assure them, so far as it was in his power to speak for the aeronautical interests of the United States, and so far as he might dare to speak for the United States in a broader way, they were in this enterprise heart and soul, and to the last fibre of their being. And if, thus far, their contributions had not come up to their hopes and aspirations, he believed they were learning rapidly that the time of probation was drawing to a close, and that they might in the end be able so to quit themselves as to merit perhaps some meed of approval from England, the great Mother Country.

Lord MONTAGU OF BEAULIEU then moved a vote of thanks to Sir William Weir for presiding. Sir William had made his mark, he said, when he entered the service of his country as Director-General of Aircraft Production. He felt quite certain that he would make an equally significant mark, and have an equally creditable record, in his new function as Secretary of State to the Royal Air Force. Sir William had been subjected to a little criticism of late by reason of the fact that since becoming Secretary of State he had not been represented in either House of Parliament. In the House of Lords they knew a good thing when they saw it, and it had now been arranged that Sir William Weir should take his place in that House without passing through that quite inferior sphere, the House of Commons. He could confidently assure him of a very hearty welcome, because the House of Lords always appreciated a man who knew his job.

The great honour which His Majesty had conferred upon the Society through the medium of Sir William Weir would not only add lustre to its name, but would give it a status which would be very valuable both to the Society and its members and to the scientific work which they carried on. He hoped Sir William would accept the thanks of the Society, and would transmit those thanks to the proper quarter.

Mr. WHITE SMITH briefly seconded the vote of thanks. Speaking for the aircraft industry, he wished to thank Sir William for his appreciative remarks regarding the designers and constructors of this country. It was a great reward to the pioneers of the aircraft industry, and also to those who had come into the industry since the beginning of the war, to know that their work had been so

valuable in this great war, and that the present Air Minister had, from his personal knowledge, so high an appreciation of that work. As aircraft constructors they had from time to time come constantly into touch with Sir William Weir when he was Director-General of Aircraft Production, and had then learnt to appreciate his broadminded vision and his mastery of detail. He was sure that he would continue to exhibit the same qualities in his present high office, and bring the same energy to bear as head of the Royal Air Force; and they wished him every success in his great work of smashing the Germans in the air and through the air.

The vote of thanks having been heartily accorded,

Sir WILLIAM WEIR briefly acknowledged the compliment, saying that he took their reception of Lord Montagu's and Mr. White Smith's remarks as an encouragement to him to develop the force of which he was proud, and of which he hoped to be still prouder.

The meeting then terminated.

SOME OUTSTANDING PROBLEMS IN AERONAUTICS.

BY DR. W. F. DURAND.

Ten years ago the aeroplane was a curiosity—a means wherewith, by a tour de force, a man might lift himself from the ground and make a hazardous flight through quiet air—a means to attract curious crowds to fenced-in county fair grounds to witness the marvel of a body heavier than air actually rising from the ground and moving under some measure of control through the air, and returning safely to its starting point.

What the aeroplane has become in this short but poignant decade of the world's history, and what it stands for to-day, this audience knows too well to need specification in detail.

It is perhaps well within the limits of conservatism to say that no achievement of man's inventive and constructive genius has undergone more intensive, more rapid, or more potentially significant development than has that of flying with an apparatus heavier than the air in which it moves.

It may be further noted that perhaps no technical and constructive achievement of man has ever called more largely on science and on the aid of scientific research to aid in the solution of the many problems which have presented themselves in the course of this astonishing development in aerial navigation which the past decade has witnessed.

Under the circumstances which have determined the direction and character of the development of the aeroplane during this decade, and especially under those which have been controlling during the past three or four years, it is only to be expected that at the present moment we should find ourselves with many partly solved problems on our hands, with others which we have hardly more than begun to attack on the outskirts and confronted by others still, the character and significance of which we have hardly begun as yet to apprehend.

On the present occasion we may find it not without interest to pass briefly in review some of these problems, noting their present status together with such indications as may in some cases serve to point the way toward a possible solution.

The Problem of Constructive Materials.

Perhaps nowhere is there to be found a better illustration of the interdependence of technical and scientific research and study than in the manifold advances in various technical and scientific lines which conjointly have made the aeroplane in its present form a structural possibility.

Broadly, the modern aeroplane comprises a body of some sort or form fitted with wings to provide the supporting surfaces, with a prime mover or source of power and with a propeller of some type to transform the power provided by the prime mover into propulsive work, and by the reaction of the relative air stream on the under side of the wings, to secure the sustaining or lifting force necessary to carry the weight. This construction calls for a wide range of constructive materials. Thus the body and wings, comprising the aeroplane proper, require the following fairly distinct classes of structural elements:—

(1) Those intended primarily to give form, strength and coherence to the structure. They represent in effect the skeleton or foundation on which the entire function of the aeroplane as such must depend.

(2) Various secondary elements intended to so tie or connect the principal members together as to secure homogeneity of structure as a whole,

and mutually responsive action on the part of the different elements comprised under No. 1. The elements here considered are those which, from a purely structural view-point, may be classed as struts and ties or tension members, with suitable connections and joint fastenings.

(3) Surface covering for the body and wings. This gives outer form and continuity of surface and provides furthermore the actual surfaces on which the air lifting and supporting forces may act.

Broadly speaking, the fundamental problem in all aeroplane construction is adequate strength or function on minimum weight. In no other form of engineering construction is the necessity for weight saving so rigorous. In a very real sense every ounce of material entering into the structure must be able to show a competent passport. The structural problem of the aeroplane is therefore one of strength in relation to weight. For the main elements comprising the skeleton of the structure, wood has, thus far, held the main place with metal construction steadily attracting more and more interest and assuming a place of growing importance, at least in the study of new designs.

It is not necessary to our present purpose that we should consider in detail present practice in aeroplane construction. The trend of development since the earliest days of the art has tended to show that wood construction under suitable design and safeguard was able to provide the easiest and on the whole the most satisfactory solution of the many problems and requirements which aeroplane construction presents, and so we have been content, for the most part, with this type of construction.

We may, however, be well assured that no matter how good may be any solution which we may reach of the many problems presented to us in the industrial arts, there are, as a matter of fact, series of better ones only awaiting our patient study. This is indeed a fundamental truth of which we should never lose sight. We may be, for the moment, satisfied with our solution of a problem in technical industry; we may be able to see nothing better, and yet we may be well assured that, as a simple matter of fact, there is something better. This is a perfectly safe assertion, if only as based on the law of probability of our having, at any given time, reached the final optimum possible combination capable of furnishing a solution of the problem.

Thus, as applied to the problem of constructing the framework of the fuselage of an aeroplane or of combining together wing spars and ribs in such manner as to form a wing skeleton, we may be sure, however satisfactory our present practice may seem and however good it may really be, that in reality it is not the best and that long series of better solutions only await our intelligent and patient study.

In this and in all such problems there are always two fairly distinct though inter-related parts.

(*a*) What materials are best suited to the purpose in view.
(*b*) What disposition shall be made of the materials adopted.

Thus, in the case of the fuselage, granting wood material to be adopted, there remains the question as to the very best distribution of such material as between the main longitudinal elements, or longerons, and the intermediate elements; also as to the extent to which reliance may be placed on the outer covering, especially if of ply-wood. What aeroplane designer can feel sure that, even with given materials, he has reached the optimum distribution of function as between the main and secondary elements of the fuselage and of a ply-wood outer covering?

Much less, what aeroplane designer can feel any confidence in having now reached an optimum combination, once we admit the possibility of metal construction, or of some combination of metal and wood, with all the possibilities of the

new light metal alloys and of the new alloy steels with their astonishing physical characteristics.

So far as conditioned by the application of the ordinary loading tests, static in character, and aside from the possible results of dynamic attack, shock, long continued vibration, etc., we may perhaps frankly admit that the present state of metallurgy is able to supply us with material, either in the way of light aluminium alloys or special steel alloys, which if properly used, will enable us to meet all such static tests in an aeroplane construction, and on even terms or better as regards weight compared with wood.

If such is the case, it certainly stands before us as a problem for the near future to pass in review most thoroughly the entire range of constructive materials, metallic as well as wood, and to determine, in the light of the experience which we are so rapidly accumulating during these days of storm and stress in military aeronautics, the combinations of materials which may assure the most efficient service on the minimum of weight.

In connection with this search for new and better materials, must go hand in hand, search for better modes of combination in the structure—in other words, better structural design. It goes without saying that the best general type of design, in the way of the distribution of materials, forms and proportions of members, etc., will vary with the class of material employed. There must be some optimum design with wood. There will likewise be another and undoubtedly a different optimum design in the case of steel, and again different in the case of aluminium or other alloys. Thus the search for the best final combination is a search for an *optimum optimorum*: for the best possible material and for the best possible design using such material.

What order of saving may be looked for in the near future from any such search it is, of course, idle to predict. Could we however approach somewhat closely to the best use of the best combination of materials even now available in the field of engineering construction and without waiting for new and superior materials which the metallurgical art will doubtless be able to furnish, it seems not unreasonable to anticipate the possibility of a marked saving in weight without loss in strength or security.

This then stands out as one of the great problems of aeronautic engineering, that of the best materials and of their best use. Much has already been done, but much yet remains, and rich rewards most assuredly await patient and well directed work in this field.

The Problem of Size.

One of the most interesting of the problems presented to the aeronautic engineer is that of the limiting size and carrying capacity of aeroplanes. Is there such a limit? If so, what is it? Why is it? And how may it be removed or extended?

In dealing with this problem we come, of necessity, into contact with the laws of similitude of geometrically similar structures. It is well known that under simple modes of loading, geometrically similar structures of wing and fuselage will have similar factors of safety under equal unit loads. But for such structures, if strictly similar geometrically, the weights themselves will increase as the cubes of the similar dimensions, while the areas of wing or supporting surface will only increase as the square, and hence the ratio of weight to area will continuously increase as the linear dimension.

Under these circumstances, it is readily shown that, in accordance with the relation of the factors involved, there will be, for any given speed, some size for which the lifting capacity over and above the structure itself will be a maximum and above which the lifting capacity over and above the structure will become less

and less with increase in size, gradually reaching zero for some value of the size of the structure. This would mean that at such point the supporting force developed at the speed in question would be just enough to lift the structure itself from the ground, but with no reserve for additional load.

This is, of course, a definite law derived from well known principles of geometry and calculus, and if it were the whole story, it would indeed tend to raise an insuperable bar before continued expansion in size. If such were the case it would mean in effect that increase in lifting capacity could only be reached by the following measures:—

(1) Reducing to a minimum the relation of weight of structure to area. That is, general improvement in the programme of design and reduction of weight of structure in relation to supporting surface.

(2) Reducing to a minimum the resistance of the plane at the given speed and likewise the relation of weight to horse-power.

(3) Raising to a maximum the relation of lifting force to area, consistent however with the decrease of the total propulsive resistance of the plane.

Were we indeed subject, without recourse, to the operation of this law of mechanics and geometry we should be in a sorry state regarding the future development of the aeroplane as regards size and carrying capacity. We should be limited strictly within the bounds of the developments made possible by improvements and advances along the lines as indicated above. But fortunately for the future of aerial navigation, we are not so limited and there seems no reason why, at the present time at least, we should need to anticipate any especial limit as necessarily imposed on aeroplane construction, as regards either size or carrying capacity.

We are able to escape from the consequences of this law by reason of two facts.

(1) It is not necessary that a large element of an aeroplane, a wing in particular, should be geometrically similar in structural characteristics to a small one. For a certain size the structural elements will partake of certain characteristics. As the over-all size increases, these elements may take on new characteristics. Those which had been solid may now become hollow or of lattice or built up form. The law of geometrical similitude will not hold and the weight will not necessarily increase in ratio with the cube of the over-all linear dimensions.

(2) It is by no means necessary that a large aeroplane shall be, in its general form, a geometrical copy of a small one. While both will have similar elements, such elements need not be the same in number or arrangement. In fact one of the most obvious of means for increasing lifting power is to increase the number of the wings or lifting elements. There is no reason, at least structurally, why wings and connecting elements should not be increased in number beyond anything now in use or even considered—increased to a point which would give a size and lifting power great enough to meet any demands which we can now formulate or which the future seems likely to present.

Structurally, therefore, the problem of increased size presents three problems as follows:—

(1) The structural problem of so developing the character of the elements of aeroplane construction such as wing spars, longerons, struts, ribs, etc., that with increase in over-all dimension the weight shall not increase sensibly faster than as the square of such dimension.

(2) The structural problem of combining the larger elements of aeroplane construction such as wings, fuselages, or engine nacelles with their connecting structures, in such manner as to secure, for a given wing area, the minimum weight of secondary structure.

(3) The aerodynamic problem of combining multiple wing elements in such manner as to reduce to a minimum the interference of one with another. This is a problem which opens fascinating possibilities to the student of experimental aerodynamics—a problem on which already some beginnings have been made, but one far from a final or as yet wholly satisfactory solution, and one on which the future development of greatly increased size and carrying capacity seems destined to largely depend.

In short, then, so far as increase in size is concerned, there seems no reason to apprehend any particular limit, or any serious difficulty on the part of the scientist and the engineer in meeting the demands of the future in these respects. The difficulties seem no greater than those which have been overcome in the case of ocean shipping as shown by the continuous development from the early beginnings of the application of engine power to ocean navigation during the first half of the last century down to the mammoth floating structures of the present time; and if we may take any indication from the accelerated rate of progress which has characterised the entire history of aerial navigation, we may feel confident that we shall not have to wait a half or three quarters of a century for a parallel development in the latter field.

Variable Wing Area or Variable Wing Camber.

To mention only one of the many remaining problems which are connected with the design and construction of the aeroplane itself, a word may be said with regard to the problem of variable wing area. Broadly speaking, the ideal aeroplane should be able to change its wing area in accordance with the conditions and circumstances of flight. For ease in getting off the ground at a moderate speed, for ease in landing likewise at a moderate or low speed, there is need of a relatively large area of wing or supporting surface. For the attainment of high speed, reduced wing areas are needed, and are furthermore sufficient for the support of the weight at such high speeds. The supporting force gained by a given form of aeroplane wing depends on the area, the speed and the angle of attack and there will be some combination best for each set of conditions. To meet these conditions, varying from time to time throughout the course of a flight, a correlative variation in wing area is needed.

To some extent the same ends may be met by changing the camber or curvature and form of the fore and aft section of the wing.

Thus, when the camber or fore and aft curvature is increased, the form will be more suitable for landing at a reduced speed, while with curve flattened and camber reduced, the form will more readily favour the attainment of relatively high speed.

The problem of an adjustable wing, either as to extent of area or camber or both, is a favourite one with students of aeronautics and we may hope for some measure of useful and practical solution. Thus far, of the many devices and forms proposed, none has so far fully justified itself as an altogether satisfactory and practical solution of the problem.

Motive Power.

Passing now to the motive power and its application to the propulsion of the aeroplane, a most interesting and important series of problems challenges our attention. Only the more important can be noted here.

Fuel.

One of the most important of these is that of fuel. What is to be the future fuel for the aeroplane, or for aerial navigation in its wider aspects? How long

will our stores of crude petroleum oil from which we now obtain our petrol or essence or gasoline, as it is variously termed, continue to furnish this all-important element in the present programme of power development? Doubtless there are large stores of petroleum oils yet undiscovered, but we may safely assume that we are using up a supply in the nature of a bank deposit. We are using our principal and not living on the interest. So far as we know, nature is not now engaged in making for us petroleum oils, certainly not in any proportion to our rate of expenditure. To such a general programme of consumption, there is, of course, but one end, ultimate exhaustion. This is, of course, only one phase of the overshadowing menace which the modern social and industrial world must face some time when our present supply of carbon and hydrocarbon fuels begins to become exhausted, unless indeed we develop or discover in the meantime some other source of energy which will adequately take their place. This is perhaps a question which need not seriously concern the present generation, but when we take a long look ahead—a look for example as long as that covered by the development of Europe from the days of the Cæsars or even from the time of, say, Galileo —we may realise with startling emphasis the need of foresight with regard to a source of energy adequate to the world's demands. Various ages have been designated as of stone, bronze, etc. The present might well be designated as that of natural energy. Our entire civilisation, in a material sense, rests upon the utilisation of sources of natural energy which are not inexhaustible and which are, in fact, becoming exhausted, in some cases, with menacing rapidity. In the meantime we must, and presumably we shall make some shift to tap efficiently other sources now known, or we may haply discover sources which to-day lie beyond our present vision.

A long look ahead for aerial navigation therefore shows that if the present line of development is to continue, there will be a serious problem to be met sometime, and that perhaps before many decades—the problem of a fuel suited to the needs of aeronautic prime movers, at a time when present petroleum sources will no longer yield the supply which we now accept and use with so little thought for the morrow.

But with regard to the question of fuels, we need not go so far afield as to look into the coming decades for interesting and important problems. Perhaps the one most pressing for present solution is the question of what is the best fuel for the modern aviation engine, having in view the three requirements—power, economy, with reliability and durability. Out of the exigencies of the present war have come many serious and extended researches relating to the problems of military aviation, and of these none is perhaps of greater significance regarding the future of commercial aviation than the studies which have been made regarding aviation fuels. While matters relating to the problems of military aeronautics must be spoken of with much reserve, it will perhaps be permissible to say before this audience that from these studies three principal results seem to have been rather definitely established. These are:—

(*a*) As between the various grades of aviation motor fuels which have been used during recent years, and comprising a rather wide range of composition and of physical and technical characteristics, there is but little to choose from the standpoint of power or economy alone. This assumes, of course, that the fuel is a genuine motor fuel and the results regarding power or economy relate to a period of effective operation under such fuel. It must not, however, be assumed that there are *no* differences in power or economy traceable to the fuel employed, for such is far from being the case. It is however within the limits of reasonable statement to say that such differences are relatively small and under most circumstances would not, of themselves, constitute a determining or controlling factor.

(*b*) As between such motor fuels marked differences do seem to be indicated as regards their influence on the life and reliability of the motor, especially on long time tests, or in actual service on long time flights.

(*c*) For the various fuels, in order to realise the best results either as regards power, economy, or life and reliability, special and individual carburator adjustments are necessary, and such as can only be determined by trial under actual working conditions.

It may perhaps be further said that the problem of an excellent and reliable motor fuel for aviation purposes seems to have been satisfactorily solved. Its specifications and range of characteristics, physical and chemical, are pretty well established, and so long as our source of motor fuel supply is to be found in petroleum derivatives, we seem to have reached a reasonably satisfactory determination of the best combinations of such derivatives for the various requirements of aviation service. These characteristics, which must be considered as a part of the great body of military information and which cannot for the moment be put down in plain print, we may hope will, in due time, become available in the arts of peace and for the development of commercial aviation in its various fields of promise.

The Engine.

With the problem of fuel, that of the prime mover or engine is closely related. Is the present type of engine to continue, or is it only a passing stage on the way to some more perfect form? This is a question, interesting indeed for speculation, but hardly to be considered in comparison with actual present moment problems. The present engine and its application to the propulsion of the aeroplane does, furthermore, present no lack of interesting and important problems, and among these a few of the more pressing may here be noted.

First, the problem of gross power. How much power can we put in an aeroplane or airship of no matter what type or form? This divides immediately into three subsidiary problems as follows:—

(1) How much power from a single cylinder?
(2) How many cylinders for a single engine?
(3) How many engines for a single airship.

In the way of power per cylinder we are now reaching close about 40 h.p. as a maximum.

In the way of cylinders per engine we have reached a stage of development where the 12-cylinder engine is quite a standard type and higher numbers such as 16 and 18 represent only questions of detail. It is not too much to say that the 600 h.p. engine is quite within the reach of present practice and may be realised as called for. We have long since become accustomed to two and three engines on a single plane and are now seeing four engines in various recent designs. It is therefore clear that if a power plant of 2,500 h.p. on a single structure is wanted, it is quite within the scope of present practice to realise and provide such a plant.

And if four engines of 500 or 600 h.p. each, there is no reason why the number may not be increased, at least to a point beyond the present apparent need for power on a single structure.

On the other hand, it must be admitted that, having in view the limitations of present practice, the most simple and in fact the only reliable way of extending power is by a multiplication of the number of cylinders rather than by an increase in the size of the latter. The fact that a 2,000 h.p. equipment would presumably require from 40 to 60 cylinders shows the formidable degree of multiplication of small elements required to realise such a result. The real problem of size or

capacity of engine is therefore one of power in a single cylinder. What can be expected in this direction, and in what way shall search be directed?

The present limitation arises largely as a matter of cooling and it is in this direction that search may well be made for ways and means of effectively increasing the power capacity of a single cylinder in an engine of the aviation type. This is a problem which is distinctly outstanding and well worth our serious attention and study.

The Carburator.

Another problem connected with the engine is that of the carburator. At the start of aeronautic engineering the carburator naturally took its initial form and arrangement from the already fairly well developed automobile engine carburator. This was but natural since both engines are of the same type and both use the same general form of fuel. In respect of the conditions of operation, however, there is a marked and important difference. The automobile operates at or near a fixed level and hence in an atmospheric medium of sensibly fixed pressure and density. With the aeroplane the case is very different. The latter may change its level by thousands of feet in a few minutes or even seconds, as in vertical or nearly vertical dives, rapid spirals, etc. This difference in the conditions of operation introduces a factor of distinct significance and of great importance in the design and disposition of the carburator. Experience in the air has clearly shown the importance of this new factor, and it is not too much to say that the problem of the entirely satisfactory carburator, capable of automatically answering to the various atmospheric conditions under which it must work, is distinctly an outstanding problem. It is true that much progress has been made and as the result of laboratory research, checked by actual experience in the air, we now know much better than, say two years ago, the fundamental conditions which must be met by the carburator for the aeronautic engine. The present solution can hardly be considered as final however, and we may fairly admit that the whole problem of carburation, including the manifold supply of the carburetted mixture to a multi-cylinder engine, should, as soon as may be, receive a thorough and fundamental re-study in the light of the information to be drawn from the experience of the past three or four years.

Ignition.

Another problem which we should view as outstanding is that of ignition. It is true that ignition, as now realised with the best equipment, seems to be fairly reliable and effective. But the whole programme is open to the objection of requiring an entire electric power plant of a highly specialised type, together with electric conductors and the spark plug for producing the spark between the discharge points within the cylinder. This ensemble, comprising electric generator or magneto, electric cable, distributor for sending the spark with proper timing to the various cylinders and spark plug with discharge points within the cylinder, represents a very complicated and highly specialised device for producing the initial ignition within the body of compressed fuel mixture. In its present state it is a marvel of scientific and technical development, and it does its work; but it is complicated and subject to many possible modes of derangement, and, as we all know, has been and is still the seat of some of the most serious of the engine difficulties to which the power plant as a whole is subject.

I have never been able to persuade myself that this exceedingly complicated and specialised auxiliary equipment was to be the final solution of the problem of producing ignition in an internal combustion engine. If we can anticipate the explosion engine of the year 1968, assuming that our grandchildren are still dependent on hydrocarbon fuels at that date (and furthermore that they are still available) it would seem as though some more direct and simple mode of initiating the

combustion in the cylinders would have been found. Still, otherwise, we may say that on the law of probability, the chances are overwhelmingly against our having at the present moment developed the very best method of ignition. The laws of physics and chemistry, by a probability which almost reaches certainty, contain some potential combination of factors which will permit of eliminating much of the complexity and delicacy of adjustment which is so characteristic a feature of the present mode.

It is perhaps proper to add here that studies in this direction have already been made, and with results which offer promise of interesting developments in the future. The path of perfection is likely to be not a short one, however, and we can see no prospect of any development in the to-morrow of progress likely to displace electric ignition. There must, however, be some better way, and if not to-morrow, then some other morrow should see it made available for use.

The problem of ignition is then one which is distinctly outstanding, one which by its importance merits the most careful study, and one which offers at least reasonable ground for hope of a successful and relatively simple substitute for the present mode.

Maintenance of Power at Altitude.

We come now to a problem of the very highest present and future importance, that of maintaining the power of the engine at high altitude.

The situation as it develops in the case of an aeroplane mounting to higher and higher levels in the atmosphere is readily appreciated with a moment's thought.

The power of the engine arises from the combustion of vapourised hydrocarbon fuel. The power per cycle for a given cylinder will therefore, to a first approximation and assuming a sensibly constant efficiency of thermodynamic transformation, vary directly with the weight of the fuel which can be burned per cycle. But this in turn depends upon and is conditioned by the amount of oxygen which can be drawn into the cylinder per intake stroke of the cycle. But the oxygen is brought in as one of the constituents of the atmosphere and hence the amount of oxygen available per intake stroke will depend upon and be directly proportioned to the amount of air which can be drawn in. But in terms of volume, just a cylinder full, or more exactly, just the volume represented by the piston displacement in moving from one end of the stroke to the other, can be brought in. Hence, we may at least depend on what we may term a cylinder volume of air no matter where we are. But just here arises the trouble. The actual weight of air depends conjointly on the volume and on the density, and unfortunately for the aeronautic engine, at least, the density of the atmosphere decreases steadily with altitude, so that at 15,000 feet, for example, the density is only about 60 per cent. of the normal density at the earth's surface. It is clear then that an aeronautic engine, other things equal, will draw in at this altitude, per intake stroke, only about 60 per cent. of the weight of air as compared with the indraft at the earth's surface. Hence, it will be able to burn only 60 per cent. of the fuel and with equal efficiency will develop only 60 per cent. of the power.

But here we must stop for a moment and inquire as to the effect of such reduction of power on the speed of the aeroplane. We know that, other things equal, the resistance of an aeroplane to propulsion through the air at uniform speed varies directly with the density of the medium. Hence, at the same speed as near the surface of the earth and with the same attitude or angle of attack, the aeroplane at 15,000 feet elevation would experience only 60 per cent. of the resistance and would require only 60 per cent. of the thrust, and at constant revolutions of the propeller would require only 60 per cent. of the power from the engine. Hence, it appears at first sight as though we had lost nothing in speed by the reduction of the power of the engine. If the latter has been reduced to

60 per cent. of its amount at low levels, so has the resistance and power required, so that the speed realised should remain the same.

Such would, indeed, be the case if this were all of the story; but, unfortunately, other considerations enter and the simple relation of uniform speed at varying altitudes cannot, as a matter of fact, be realised without compensating features.

Thus, if at a constant speed and constant angle of attack for the wings, the resistance to propulsion is only 60 per cent. as great at the altitude of 15,000 feet as on the ground, it is, unfortunately, the same for the lifting force developed by the wings. This also is only 60 per cent. as great, while the weight of the machine remains sensibly constant at all altitudes. Let us pause long enough to grasp clearly this fact, that while, at constant speed and angle of attack, the resistance, the lift and all other aerodynamic forces involved vary directly with the density of the air, and hence decrease with the altitude, the weight of the machine, and hence the lift necessary for support, remain sensibly unchanged. Hence, at the same angle of attack the lifting force at altitude and under the same speed will no longer support the plane, and unless something is done, it would be unable to maintain at such speed continuous horizontal flight.

Two courses are then open for consideration as follows:—

(1) We may seek to increase the speed until at such increased value the lift will equal the weight of the plane. Under the conditions assumed, this would involve an increase of speed of about 30 per cent., thus increasing the resistance to propulsion by nearly 70 per cent. or bringing it back to its value at low altitude. But this resistance overcome at the increased speed would mean an increase in the required horse-power of 30 per cent. as compared with that normally developed at low level, while with the actual indraft of air and even allowing for the increased speed, only some 78 per cent. of this, or 60 per cent. of the needful amount would be developed. Hence, no such speed could be realised and the support of the unvarying weight in the rarefied air cannot be obtained in this manner, and must be sought otherwise.

(2) Instead of seeking for the necessary lift by increased speed we may seek it by changing the angle of attack; by changing the flying attitude of the plane so that at the same speed, for example, the lifting force will be greatly increased. In this manner the needful lifting force may indeed be realised. But unfortunately with the increase in lifting force will come also an increase in head resistance, not necessarily in proportion, but still a definite increase. This will mean that the actual resistance at, say, 15,000 feet elevation will be greater than 60 per cent. of that at low elevation and hence with 60 per cent. of the power available per cycle, the original number of revolutions cannot be maintained and a reduction in speed will result. With this reduction in speed will come a further loss in lifting effect and need for a further change in the angle of attack with increased head resistance; until finally, at some reduced speed, a condition will be found where the needful support for the weight of plane may be realised and the resistance to propulsion can be met by the thrust or pull developed at the propeller. Under these conditions, horizontal flight again becomes possible, but at a speed somewhat below that corresponding to low altitude conditions.

But this is not all of the story. In addition we must reckon on a diminished efficiency of the engine with decreased power, and with the probability of a loss in propeller efficiency with the resultant change in speed. Thus, if an engine is primarily designed to work at its best efficiency and under its best conditions at or near full atmospheric pressure and density, it will not work with equally good efficiency at high altitudes in rarefied air and when developing only about one half the power for which it is primarily designed.

All of this means, in brief, then, that at an altitude of say 15,000 feet as compared with low levels, the plane must fly at a less advantageous angle of

attack and hence with more resistance; while the engine will be able to burn only about 60 per cent. as much fuel and may transform the resulting heat less effectively than when at low altitudes. Hence, the power developed may be somewhat less than 60 per cent., and thus insufficient to maintain the same speed; and with diminishing speed there may be further loss of efficiency in the propeller and a further loss of speed until finally matters become adjusted at some value usually definitely and sometimes considerably less than that corresponding to low level conditions.

Hence, as an over-all practical result an aeroplane normally loses horizontal speed as it ascends to higher altitudes.

Confronted with this fundamental fact, what is to be done? Such loss of speed, especially in a military sense, is or may become very serious, and one of the large and definitely outstanding problems in aeronautic engineering at the present time, centres about the possible ways and means of meeting this condition.

The obvious proximate solution is to avoid, so far as may be, the decrease in the amount of air handled per intake stroke of the piston as the plane ascends to higher and higher altitudes.

Broadly, two courses are open. First, we may definitely and frankly design the plane and engine for a certain desired performance at a given altitude, say 15,000 or 20,000 feet. This is a straightforward problem in aeronautic engineering. Given the desired schedule of operation and the altitude, we can determine the resistance to be overcome and the horse-power required, and can design the engine accordingly. In such case the volume of the cylinders will be suited to the rarefied air in which the engine is to work and all proportions and details will be worked out on this basis.

It will be obvious that such an engine will have much too large a piston displacement volume when at low altitude. That is, it will be over size and over powered relative to the plane. In fact, operation near or on the ground under the same adjustments as at altitude would be quite out of the question. Means must therefore be provided for reproducing, when on the ground or at low altitudes, substantially the operating conditions at high altitudes and low air density; that is, the conditions for which the engine was designed. This may be most conveniently done by throttling down the air intake so that while air at or near full sea level density may surround the engine, it will be reduced in pressure at the intake throttle to such a degree that the amount actually taken into the cylinder will only equal that which would normally enter, without throttling, at high altitude.

On the other hand, we may definitely design the engine for operation at or near sea level and with size of cylinders and all proportions and adjustments worked out accordingly, and then by a supplementary device endeavour to maintain or to nearly maintain such conditions within the engine itself, even if it is at high altitude and surrounded by air of a lower density.

This solution calls for some supplementary form of compressor or equivalent device which shall operate on the rarefied air as a first stage and raise it from the low pressure, characteristic of the altitude, up to or nearly to normal low altitude pressure and density.

Each of these alternatives represents a perfectly possible solution. Each has its special advantages and disadvantages. Each has its advocates as a solution of this important problem.

The first solution is the simpler of the two, since it involves no special or additional device for compressing the air. It does, however, mean extra weight in the engine which is always there and which will reduce correspondingly the net carrying capacity of the plane.

On the other hand, the compressing device of the second solution is not easy

to realise satisfactorily and it also involves extra weight, though presumably less than in the case of the first solution. Again, its operation as a separate or independent unit for realising a preliminary compression of the air is less efficient than to do the whole compression in the engine itself and by the engine piston as in the first solution. Only extended and careful trial will presumably be able to finally decide which is on the whole the better solution of the two.

The reserve necessary with regard to military matters makes it unwise to attempt to give any account on this occasion of just where the matter stands with regard to this problem; but it will at least be safe to note that it is a problem which is attracting much attention and study on the part of the various allied Governments, and that much valuable information is being developed, and on which we may hope that some satisfactory solution may be based.

The Airscrew.

We shall now turn our attention for a few moments to one of the most intricate and hence one of the most interesting of the many problems presented to us by the aeronautic art, that of the airscrew or propeller.

The function of the airscrew is, of course, to take the torque of the engine and to transform it into a propulsive thrust; or otherwise to take the power given by the engine to the crank shaft and transform it into driving or propulsive power for the aeroplane. The problem is further complicated by the fact that expressed in terms of a power relation, it is not simply the question of an engine handing so much power over to the airscrew for the latter to transform into propulsive power. Instead, the power which the engine itself can develop is dependent on the propeller and likewise on the aeroplane to which they are both attached. We have here, in consequence, a series of complicated implicit relations, and from which the propulsive characteristics of the plane-propeller-engine combination take their origin. In fact, it must never for a moment be forgotten that the moving aeroplane is in effect an aeroplane-motor-propeller combination and that no one of the three can be determined independent of the other two.

Without entering into any detailed discussion of this problem, it will be clear that the airscrew will exercise a controlling influence on the power which the engine can develop. Thus, it is evident that an aeronautic engine, in order to develop power, must be permitted to move its pistons, to revolve its crank shaft, in other words, to make revolutions; and other things equal, the power developed will vary directly with the revolutions which are realised. Again, it is easy to see that the size and amount of surface of the airscrew blades will present a controlling feature regarding the revolutions which *can* be realised. Thus, the airscrew may be enormously over size, too large in diameter and presenting a large and unwieldy surface to the air. Suppose this to be the case with a plane of size suited to the airscrew but not to the engine. That is, the engine is far too small for either airscrew or plane. In such case the engine simply will not be able to make its normal number of revolutions. It will be held down by the excessive resistance to rotation presented under such circumstances, and may thus develop far less than the normal power which it is capable of under proper conditions. Many other combinations may occur which we cannot stop to discuss or even to mention. Broadly speaking, the plane, the engine and the airscrew, as the propelling agent, form a most closely knit combination and each interacts in a more or less controlling manner on the operation of the other two.

In order even to make a start with the problem of the airscrew it is therefore necessary to assume conditions regarding both the plane and the engine. If these conditions, as assumed, are then realised in practice and if the design has been well carried out, the anticipated results may be reached. If, on the other hand, the assumed conditions are not realised as regards the plane and the engine, then no matter how well the design of the airscrew may have been carried out, the

anticipated results will not be realised. Hence, no matter how good the airscrew may be by itself, no matter how carefully designed and constructed, no matter how faithfully it may be able to realise the conditions for which it is designed, if these are not the conditions under which it is actually placed for service, the results economic and otherwise will be unsatisfactory; not necessarily by reason of any fault in the airscrew as such, but due simply to its lack of adaptation to the conditions of operation. An effective airscrew is therefore not only one which is properly designed and constructed in itself, but also one which is permitted to operate under the conditions intended and contemplated in its design.

All this is, of course, well known, and if I have taken the time to repeat these well-known facts, it is the more clearly to bring to our minds at the present moment the fact that the airscrew represents not only a problem in itself, but also one of adaptation to and of usage with the proper combination of plane and of prime mover.

The general problem of the airscrew is by no means, however, to be classed distinctively as outstanding. Instead, an enormous amount of work has been done on it, both theoretically and experimentally, and in its main features it has been brought fairly within the limits of a solved problem. There have been three modes of approach, briefly, as follows:—

(1) The analysis, geometrically, of the blade of an airscrew into a series of elements, occupying each a narrow strip running across the blade from leading to following edge and making up, by their summation, the blade as a whole. Each of these elements or strips is then considered as, in effect, a little elementary aerofoil and for which the usual aerodynamic characteristics are readily determined, either by direct experiment on a model, or by selection or interpolation from and among the large amount of available data regarding such aerofoils which have already been submitted to experimental investigation. With such data in hand relating to the series of elements going to make up the blade, it is a matter of simple computation to combine them in such manner as to represent the action of the blade as a whole, under the conditions assumed, and thus in general terms the problem is solved.

(2) A law of similitude is assumed and a small model propeller is tested out experimentally and under conditions which permit, under the law of similitude assumed, the translation of the *observed* results for the model into the *probable* results for the full sized airscrew.

(3) Full sized airscrews are tested out as nearly as may be under flying conditions and are made the ultimate basis of design.

The limitations of method number 1 arise from the following:—

(*a*) The coefficients derived for aerofoils correspond to straight line motion between the air and the foil, whereas, in the airscrew, the relative motion is in a helical or spiral path.

(*b*) The actual velocities for which such coefficients are derived are usually for speeds not exceeding 60 or 70 miles per hour, whereas the actual speeds of the tip elements of airscrew blades may move at speeds of 500 m.h. and upward. The extent to which the usual square of the speed law may be extended to such values is not as yet fully known.

(*c*) The coefficients used are derived for the various aerofoil sections or elements individually, whereas, in the actual airscrew, they all act conjointly or collectively in making up the airscrew blade.

Application of method No. 1 cannot therefore be made except in so far as it is justified by actual and final experience on full sized forms under flying conditions.

Method No. 2 (that with reduced size models) has the limitation that the law of similitude employed is, of necessity, not exact but approximate and the degree of reliance which can be placed on results thus found can again only be determined by ultimate reference to full sized forms under flying conditions.

Method No. 3 (that with full sized forms under actual flying conditions) has the limitation of very high cost, both in equipment and time, and as a result of which only a relatively small number of forms can actually be subjected to adequate test in this manner.

Again, method No. 1 (that of computation based on coefficients determined by laboratory experiment) has the advantage of requiring only a pencil and pad of paper with a table of predetermined coefficients. No. 2 (that with the small models) has the advantage over No. 3 of relatively small cost, of permitting the tests to be carried out in a wind tunnel with all conditions under control, and finally it permits of carrying quickly through the test programme a very large number of types and forms. It should perhaps be stated here that as between methods No. 1 and No. 2, the latter is accepted as much the more reliable of the two. In fact, it is not too much to say that when used with judgment it furnishes a very satisfactory and well-nigh universally accepted method for dealing in a laboratory way with most problems of airscrew design and operation.

If we have tarried so long over these phases of the problem of the airscrew propeller, present methods of design, etc., it is in order to bring into clearer relief the parts of the problem which are not yet well in hand—the parts which *are* as yet outstanding and awaiting our further study.

These phases which thus stand out represent in effect the lack of an adequate correlation between the three methods of approach as above described.

It is obvious that if we could develop an adequate and reliable correlation between the results of the computation according to method No. 1 and the final test under flying conditions according to No. 3—if, in other words, we could adequately determine the error of No. 1 and hence the correction to be applied in any given case, then a pencil and pad of paper would go a long way towards furnishing the material for the solution of the problem of airscrew design, once that we are permitted, of course, to assume a definite set of operative conditions.

Or again, if we could know more accurately and more widely the character and amount of error to be anticipated in the use of the small models according to method No. 2, we should be in a position to use the experimented model method with better assurance of definite and reliable results for the full-sized screw later to be constructed.

It seems likely that this final correlation of computation with ultimate result may best be made in two stages. The first should comprise a careful study of the relation between the results derived by the computations of method No. 1 and the model tests of method No. 2. Such a correlation would then permit us to pass readily from the results by computation to the probable results by model.

The second correlation should then comprise a series of comparative tests to determine with sufficient generality of application, the character and amount of correction to be applied to the results of model test in order to satisfactorily reproduce the results to be expected from full-sized forms.

This would, by no means, require the testing of a full-sized form corresponding to each model. If so, there would, of course, be no use in making model tests. The whole programme might as well be carried out directly by tests on full-sized forms. It appears reasonable to expect, however, that a well selected and not too numerous series of tests, properly distributed among the various characteristics of form and of operation, would serve adequately to give the correlation desired.

With such correlations established, we should then have two methods, Nos. 1 and 2, available for the design of airscrews. No. 1 available with no more than a pencil and pad of paper (once the standard section coefficients determined), and No. 2, by model, ready to supply a vast amount of detailed information regarding operation under varying conditions, and which may be realised rapidly and effectively once the model is made.

If we have spent so much time over these matters relating to the airscrew, it is because of its importance as an element in aerial navigation, and in order that we may the better note just what part of the general problem is still outstanding.

This, as we have seen, lies primarily in the matter of the correlation between the three methods outlined. There is indeed need for continuing experimental research, especially on systematically selected forms, both model and full size; and such continuing experimental work combined with carefully directed studies of correlation will go far toward giving us an assured and adequate basis for the practical solution of the airscrew problem as applied to aerial navigation.

Reaction between Airscrew and Plane.

Perhaps the widest and most important outstanding problem in connection with aeroplane propulsion has relation to the reaction between the plane and the propeller—the influence of the structures adjacent to the propeller on its performance, economic and otherwise, and the influence of the propeller on the plane, both as regards its lift and its net resistance to propulsion. This is a field which is largely outstanding. It must be attacked chiefly by the experimental method—by model with results checked up by comparison with full scale trials so far as practicable. Time forbids more than the mention of this promising and largely uncultivated field of aerodynamic investigation.

Multiple Airscrews on One Shaft.

Of a closely related nature is the problem of the interaction of two or more airscrews on one shaft. This is a problem which is becoming of importance in connection with the increase in power of aeroplane power plants and with the fitting of more than one airscrew on the same shaft.

This likewise is a problem which must be approached experimentally—again through model research checked up by comparison with full scale tests. A beginning has been made on this important and interesting problem and we may expect, in a not distant future, to find it brought within limits of control similar to those surrounding the problem of the individual airscrew.

Airscrew with Adjustable Pitch.

In addition to these problems which relate to aeroplane propulsion in its general aspects, and more especially when for the sake of simplicity we assume that the aeroplane remains under a uniform regimen as regards external conditions, there arises a problem of very great present importance, that of some form of adjustment in the technical characteristics of the aeroplane—propeller combination permitting it to be made responsive to variations in the regimen of operation, as for example, change in the density of the air due to change in altitude, or change of regimen required for climbing flight as compared with horizontal flight.

In connection with the prime mover, mention was made of the very important problem of maintaining power at altitude in spite of the decrease in the density of the air. In reality this problem is very intimately bound up with another of scarcely less importance, that of devising means for effectively using such power for propulsive purposes. Without attempting any technical discussion of the question, it will be apparent that the whole problem of the operation of the airscrew as a means for absorbing the power of the prime mover and converting it

into the propulsion of the plane will depend on the density of the medium in which and on which it operates. Again, in climbing flight a part of the weight of the aeroplane is carried by the pull or thrust of the airscrew. In horizontal flight it is all borne by the planes (assuming the airscrew shaft then horizontal). Hence, the pull or thrust of an airscrew and indeed its whole regimen of operation may vary widely according as the plane is climbing or flying horizontally. It thus seems reasonable to conclude that for the best results there should be provided some mode of adjustment or compensation so that the airscrew, as it finds itself operating in a medium of continuously decreasing density, or as it finds itself called upon for varying amounts of thrust or pull with varying angles of climbing flight, may be correspondingly adjusted in order to give continuously the best results.

The problem is further complicated by the fact that the aeroplane itself needs a correlative adjustment. As we have already seen, the one factor in aerial flight which remains sensibly constant under all conditions and at all altitudes of flight is the weight of the plane and its equipment. The vertical supporting force gained from the reaction of the air must therefore be maintained constantly equal to this weight at least for the conditions of horizontal flight, while for climbing flight the weight will be divided and borne partly by the supporting planes and partly by the airscrew. The problem of the economic use of power at varying altitudes and under varying angles of climbing flight involves therefore the following chief elements:—

The weight of the plane.
The surface of the wings and their aerodynamic characteristics.
The angle of attack of the wings.
The speed.
The power developed by the engine.
The revolutions of the airscrew.
The area and form of the blades of the airscrew.
The pitch of the airscrew.

These various factors react and interact in a most complex manner and any attempt to discuss the problem in detail would carry us too far afield on the present occasion. Reference has already been made to the problem of wing surfaces, adjustable either in area or form. Such adjustments are, however, not yet available and at present the angle of attack is the one feature about the plane which may readily be varied. On the other hand there is no feature of the propulsive agent, the ordinary airscrew, which admits of equally simple correlative variation. What is needed with regard to the airscrew is, indeed, some means of realising an adjustment correlative to the change in the angle of attack for the plane. To this end a change of pitch is most suitable, some means of varying, at the will of the pilot, the pitch of the screw in order that with the fixed diameter and area of surface, and with the work available per revolution of the engine as affected by the density of the air, the pitch may be so adjusted as to secure the number of revolutions best adapted to the economic use of the power given out by the prime mover. This will then ensure the thrust needed to overcome the resistance of the plane at the angle of attack and speed which, taken conjointly, will give the lifting force needed to support the weight of the plane, either in whole or in part, according as the plane is flying horizontally or climbing.

All of this somewhat complicated statement means simply that what is wanted is an airscrew with blades adjustable for pitch. Such an airscrew may be realised by so pivoting the blades that they may be turned about a radial axis, thus changing their angle relative to the axis of the screw itself. Extreme changes of such a character result in a very wide variation of pitch from root to tip and in the end will result in a serious loss in efficiency. There are therefore two problems involved:—

(1) The aerodynamic problem of determining the best form and proportions of an airscrew, the blades of which are intended to be pivotable in this manner, so that under the widely changing conditions of flight which may be met with. there may be effective operation and a well sustained efficiency.

(2) The mechanical problem of so designing and building an airscrew with adjustable blades that it will meet the rigorous requirements imposed upon it by the exacting conditions of aeroplane navigation.

It is perhaps not too much to say that the first problem is already well in hand. We know reasonably well what forms and proportions to give to such an airscrew, and if it were only a matter of design or of the determination of form and proportion, the problem could hardly be called outstanding.

As much cannot be said regarding the second problem. The practical construction of an airscrew with adjustable blades is not an easy matter. Several modes of construction have been attempted, but with only moderate success. The problem is clearly defined, of the highest order of importance, and is outstanding as one of the appliances for which the art of aerial navigation is definitely in waiting.

Stability and Control.

The three fundamental requisites of an aeroplane are strength, movement, and stability with control. We have noted some of the problems arising under the requirements of strength, and movement or propulsion. We may now turn very briefly to glance at the situation regarding stability and control. Any detailed discussion of these problems would be quite out of the question on the present occasion, and time in any event will only allow us a brief glance at the general situation.

Regarding stability and control it is not too much to say that the general principles underlying these characteristics of an aeroplane are now reasonably well understood, due largely to the splendid theoretical and experimental investigations initiated by British scientists and to which certain workers in the same field in the United States may have contributed something, and by no means overlooking certain important contributions by French and Italian investigators. These investigations, both analytical and experimental, have placed the study of these subjects on a reasonably sure foundation, and have served to mark out the way to secure any desired degree of stability which may be desired or which may be consistent with other valuable qualities. We are here confronted with one of those situations, so frequently encountered in scientific and technical work, where a choice must be accepted on some middle ground between wide extremes, and where the attempt to secure some desirable quality in high degree may lead to a limitation of desirable qualities in other directions.

So it is with stability and control. If stability is carried to an extreme then mobility and quickness of manœuvring are reduced and control in the sense of ready response is lacking. For military purposes, especially for machines of the fighting type where mobility is of the highest importance, this would be a serious shortcoming, and hence such machines cannot be given too much stability in the ordinary sense of the term. On the other hand, for heavy machines of the bombing type, where mobility of evolution is not so vitally important, the margin of stability may be greater. Going to a still further extreme, it is perfectly easy to build a safe moderate speed family carriage sort of machine which will be stable and secure, under almost any conditions likely to develop. Such machines would be scorned by fighting pilots, but when civil aeronautics begins to come into its own after the war and under peace conditions, and there comes a demand for safe machines for civil purposes, including family outings for the week-end from the city to the country or to the sea coast, then we may anticipate a larger

recognition of the qualities making for safety and stability, and we shall find machines provided having such characteristics and in practically any desired degree. Here again, however, there will be degrees of choice, because it will be found that with too high a degree of stability, what may be termed the riding qualities of the plane will be poor, while with low stability the riding qualities may be much smoother.

The general problem is therefore pretty well solved so far as the ground work is concerned. This does not mean, however, that there is nothing further for us to learn in this connection. There are many problems of a detailed nature inviting the student of this fascinating field of study and the solution of which will serve to round out and broaden our general grasp of the subject. In particular, we need further study on the interaction between elements which ensure stability and those which permit mobility and readiness of response to control agencies, to the end that we may control more effectively the combinations which may be desired regarding stability and mobility of evolution.

Again, while the elements of control are well understood, there is room for further study as to the best means of actually developing the control forces required and of applying them to the plane itself. These are partly aerodynamic and partly structural problems, each phase reacting more or less on the other.

One instance of problems of this character will serve to illustrate the type.

Thus, we know that an aeroplane is provided with rudder surfaces of two kinds, one to determine movement in a vertical direction, up or down, and the other to determine horizontal motion, right or left. But these motions, vertical and horizontal, assume that the plane itself is horizontal or sensibly so. However, when a plane is circling on a steep spiral or making a quick turn, it is inclined or "banked," in order to avoid side slipping, until, in extreme cases, the wings are nearly vertical, and frequently much more nearly vertical than horizontal. In such cases, the functions of these control services are reversed. Those which, with normal aspects, serve to produce movement right and left will now serve to determine motion rather in a vertical direction, and those which formerly served for movement up and down will now serve to determine motion to the right or left. For intermediate angles of bank, each set of control surfaces will give control forces in both directions, up or down and right or left.

Now, it is by no means sure, having in view this double and interchanging function between these two sets of surfaces, whether we have as yet realised the ultimate and best arrangement either as regards the surfaces themselves or their control by the pilot.

It seems decidedly probable that we have not and that some arrangement yet remains to be devised which will be more effective in the matter of this double and interchanging function of control, and simpler in its relation to the pilot.

This and other like problems are still awaiting investigation and offer a delightfully promising field for the further study of the aerodynamic engineer.

Armament and Instruments.

There still remain two large and important fields, rich in aeronautic problems. These are armament and instruments. I shall attempt no more than the briefest general reference to these two classes of problems.

Those arising under the head of armament are, of course, strictly military in character and but little of interest could, in any event, be said in a public address. Such problems relate naturally to the number, type, and size of guns to be carried, their mounting and special sights; bombs and devices for carrying, aiming, dropping, etc.; questions of armour and protection of vital parts against gunfire or shrapnel bursts, etc.

Expressed in their most general terms these problems resolve themselves into an attempt all along the line to meet the requirements imposed by the desired military uses of the plane, and to anticipate or improve upon the devices and designs of the enemy in the same fields.

Regarding instruments, little more specific can be said. This field does, however, bristle with problems of the highest interest to the scientist, and may well challenge his best efforts. It is interesting to note the extent to which the modern aeroplane has become a flying meteorological and physical laboratory. Thus, a recent list of aeroplane instruments shows some 25 or 30 different instruments and devices, not indeed all to be carried on one plane, but all included in the general aeronautic military programme, and each serving some specific and important purpose.

With these instruments as with armament, the problems reduce themselves to an effort to meet the military or the navigational and operative requirements of the situation, and in these days of war in particular, to anticipate or improve upon the similar devices and designs of the enemy.

Much of the work relating to these problems under armament and instruments is already done and well done. There do remain, however, many problems, especially of detail or of improvement, and which must be considered as outstanding; but of these I shall attempt no mention or discussion.

By way of conclusion, reference may, for a moment, be made to a problem of the most vital and far-reaching economic importance, and which will be upon us with the arrival of peace conditions. This is the problem of the best economic utilisation of the enormous investment which has been made in aeronautic production, expressed in terms of money and human time and energy, and now represented by factories, machinery and equipment, finished product, trained industrial organisations, human skill and productive capacity.

The discussion of such a problem might well occupy our careful attention for the entire hour, but I can no more than mention it here by name. We can, however, scarcely over exaggerate its importance, and the appointment of important commissions in England and in the United States for the study of the problems arising under this general head is an evidence that their serious import is appreciated, and we may hopefully await suitable measures of adjustment against the day when we may again turn our thoughts to the occupations of peace.

And so with all our problems; we can only look hopefully forward for the future to give to us such measure of answer as our patience and study may merit.

Of one thing, however, we may be sure, and that is that the day will never come when we have no more problems to solve. But, on the contrary, the number of problems still outstanding, as the years go by, is likely, rather, to increase with our acquaintance with the subject, and we may be sure that before this or any like audience under the auspices of the Aëronautical Society of Great Britain, there will never lack material for a discussion of "Outstanding Problems in Aeronautics."

ABSTRACTS.

Nature of the Reaction Due to Fluids in Motion.

A mathematical investigation is given of the laws governing the forces acting upon the walls of conduits and pipe-lines carrying fluids at rest or in motion. As a working approximation the hypothesis is made that over any section of the stream drawn transversely to the mean stream direction at that locality, the distributions of pressure and velocity are uniform.

In the first instance the hydrostatic case is discussed of fluid maintained at rest under a definite pressure head in a ring-shaped vessel of irregular form, constituting a "pipe-line," admitting of bends and constrictions. The pipe is supposed to be situated in vacuo, and to be built with its walls rigid and weightless. Considering the portion of fluid comprised between any two transverse sections of the pipe, the resultant force is computed which must be resisted by the bounding walls.

Passing to the extension of the problem where steady flow may be supposed, maintained by means of a small turbine introduced in the circuit, the resultant of the pressure forces, due to all causes, acting upon the actual walls bounding any length of the circuits, is referred to as the wall-pressure. In this connection it is recalled that in common usage the term "Reaktion" refers to the force system acting upon the walls, which is contributed by dynamic causes alone, no account being taken of the pressure acting over the transverse sections cutting off the pipe-length considered. It is estimated as the difference between the wall forces acting when the fluid is in motion and when it is at rest. This standpoint is thought liable to lead to error in certain practical calculations.

Proceeding to the calculation of the wall-pressure, expressions are first derived determining the resultant effect contributed by centrifugal forces due to the curvature of the stream flowing through a given length of pipe. It is inferred that, as regards the form of the expressions derived, the geometrical shape of the length of the pipe is immaterial, and, further, that in the intermediate portion, regions of cavitation are permissible within the fluid, which may be supposed largely filled in with turbulent fluid. Frictional and energy losses which may arise from eddy motion are said to affect the value of the final expressions only in reducing the velocity over the discharge section.

An investigation follows of the terms to be included in the wall-pressure due to causes other than those of centrifugal origin. A special length of the pipe is considered, without curvature, in the form of a truncated cone. Allowing for the acceleration forces which are necessary to produce the requisite velocity changes, the total wall-pressure is computed, both when the axis of the cone is vertical and when it is horizontal. Referring to practical application in this connection, the formulæ obtained are recommended for problems such as the calculation of the strength of screws utilised for attaching outlet chambers of various types of the walls of the conduit. Special reference is made to the cases of a tapering outlet attached at an angle to a plane wall, and of a nozzle whose discharge mouth is cut skew. It is stated that conditions discussed are approximately reproduced within the paddles of turbines.

The forces operating on the walls consequent on curvature are more closely examined. The total wall-reaction, inclusive of centrifugal effects, is investigated for length of curved pipe circuit. It is considered sufficient to examine two special cases, consisting of curved pipes of uniform bore, fitted with conical intake and discharge mouth-pieces respectively.

In the concluding sections reasons are advanced to emphasise the desirability of an improvement and a standardisation of nomenclature in the subject.—(A. Budan "Oesterreichische Flug-Zeitschrift," Nos. 1-4, Jan.-Feb., 1918.)

ABRIDGMENTS OF RECENT PATENT SPECIFICATIONS (AERONAUTICS).

COMPILED BY MR. H. T. P. GEE, PATENT AGENT.

114,858. J. W. Williams, 94, Sheil Road, and W. J. Williams, 99, Sheil Road, both in Liverpool. January 23, 1917.

Steering and Balancing.—In an aeroplane having the wings adjustable fore and aft about axes at their inner edges, the inner edge of one wing is connected to the inner edge of the opposite wing by links so that one wing moves backwards while the other moves forwards. The inner parts of the wings are cut away to leave a skeleton frame, to the front edges of which are pivoted elevators which may be arranged to act also as ailerons.

114,891. E. H. Moore, 20, Baskerville Road, Wandsworth Common, London. April 18, 1917.

Shock of Landing, Deadening, Land Wheels.—A landing chassis comprises a frame having means for guiding the end of a wheel axle against the resistance of a pair of opposed semi-elliptic springs connected together by links and secured respectively to the axle and frame. A single axle carrying two wheels may be used, or separate axles, each having a wheel at one end and pivoted at its other end to a member depending from the machine, may be employed. In one construction two side frames each comprise two convergent members connected at their lower ends by a plate on the outside of which two angle members are secured. The lower ends of these members are bent outward'y to form a bracket to which is secured a gusset plate for connecting the side frame to one of two inclined members extending to the machine frame. A plate, which may be part of the plate already mentioned, is secured to the outwardly bent parts and carries a spring. The ends of the spring are connected by links to another spring secured to a member on the axle guide between the angle members. In a modification two axles are used pivoted at their outer ends to members depending from the planes. In this form, a central frame similar to that above described is used, but the side members are brought close together at their lower ends and the gusset plate secured between them. The gusset plate has an extension slotted to take pins or rollers carried by cheeks on the inner ends of the axle and embracing the plate extensions. A spring suspension similar to that above described is used, but the links are jointed at their centres to compensate for the curvilinear movement of the axle ends.

114,950. J. D. Brunton, Wire Mills, and J. R. Rathband, 237, North High Street, both in Musselburgh, Midlothian. August 2, 1917.

Universal Joints.—In a universal joint, particularly for the stays of aircraft framework, of the kind in which a metal blank is bent to provide a circular bearing for the larger pivot or trunnion, the limbs of the blank are in contact for a short distance near the bearing, and this part may have strengthening corrugations with the object of minimising deformation of the circular bearing when the wire is strained. The smaller pivot pin passes through registering holes in the limbs of the blank and a lug fitting.

115,021. H. P. E. Siegler, 21, Rue d'Aumale, Paris. March 7, 1918. Convention date, March 16, 1917. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act.

Machine Guns.—Relates to means for controlling the firing of machine guns between the propeller blades of aircraft, and consists in operating one or more guns from a shaft driven by the propelling motor, the usual recoil or gas operation of the gun being dispensed with. The invention is shown applied to a short recoil Vickers machine gun having a breech block connected by a rod to a crank mounted on a shaft which is carried by recoil plates extending rearwardly from the barrel. The motor-driven shaft drives through worm gearing, not shown, a shaft carrying a cam on which bears a roller on a spring-controlled pivoted lever. One arm of this lever engages a roller on the crankshaft to open the breech of the gun at properly timed intervals, the breech being closed by the usual fusee return spring. A hand-operated cam engaging an extension on the lever serves to move the lever to inoperative position when desired. An arm carrying a roller is connected with the lever by a pin which shears under abnormal resistance. The shaft carries a cam operating a safety sear engaging the recoil plate, and an eccentric operating through a rod and a firing lever on the usual sear carried by the lock of the gun. A spring-controlled hand sear similar to the safety sear may be actuated by the gunner through a Bowden wire. The shaft may carry two or more sets of cams for operating and timing the firing of two or more machine guns.

115,060. C. Prost, Genay, Ain, France. March 20, 1917.

Aerial Machines without Aerostats; Planes, Arrangement of; Propelling.—Relates to flying machines of the kind in which the supporting planes are reciprocated along inclined guideways by means of endless chains so as to act, in the forward stroke, merely as supporting planes, and in the rearward stroke as propelling surfaces. The planes are connected to endless chains, passing over wheels, by cross rods, engaging between a fixed arm and spring-hinged arm on the plane. During the forward stroke along the upper side of the chain the planes are held parallel to the chain by the engagement of the rods and pins in guide slots. At the end of the forward stroke each plane is released from the rod by the engagement of the spring-hinged arm with an abutment, after which the rod, carried on by the chain, engages a lever thereby raising another lever, the heel of which forces the pins down into guide slots. The plane falls about the pins and is again taken up by the rod which engages a lower guide slot during the rearward stroke. At the end of this stroke the pins slide up slots and enter the hooked end of a lever. As the rod rises farther the plane is rocked about an abutment whereby the rear end of the plane and the last mentioned lever are lowered, this movement of the lever operating a right-angled lever to withdraw bolts so as to allow the rod to pass and, by raising a catch, to enter again its guide slot. The pins also enter this slot and pass a catch, the forward stroke then proceeding as before. If the motor stops, the planes on the lower chain path may be lowered into position to act as supporting planes by the following device. A guideway mounted on arms carries pulleys over which passes an endless chain. When the motor stops, the pilot raises the guideway by means of a lever, whereupon the chain engages and raises the lower end of another lever, which, being pivoted to the plane, withdraws the pins from the guide slots by means of cords. The planes then fall, restoring the lever to its normal position and thereby engaging the pins in the lower guide slot. Two sets of planes may be provided, one at each side of the machine.

Planes, Construction of.—Each plane is composed of a flat frame surmounted by a convex frame on which the fabric is stretched.

115,260. S. E. Saunders, Ltd., S. E. Porter and F. Goatly, Columbine Works, Medina Road, East Cowes, Isle of Wight. April 28, 1917.

Ship's Fenders.—A pneumatic cushion or buffer for use on aircraft or as a fender for a boat comprises an inner inflatable tube contained in a flexible but inextensible jacket secured to the framing of the craft and provided with a shoe. The jacket is of leather or canvas and has leather slings by which it is attached to the craft. The jacket bears against a batten. A flap is provided at the rear end of the jacket for the introduction of the tube, which has a cord attached to its front end to facilitate reintroduction after withdrawal from the jacket. A flanged guard protects the inflating valve.

115,445. L. H. Mackay, 6, Wood Street, Shincliffe, Durham. December 5, 1916.

Launching Seaplanes, etc.; Buffer Stops.—A device for launching seaplanes and the like from ships or land comprises a carriage supporting the seaplane and adapted to be moved along rails by a push-roller moving in a curved guide and fixed to a rotating endless cable, a buffer stop being provided for arresting the carriage, whereupon the seaplane commences its flight. A form of guide is shown along which the push-roller is moved by means of an endless cable driven by a pulley, the push-roller engaging the rear edge of the carriage provided with rollers engaging rails. The push-roller is mounted on a pin fitted with rollers engaging slots in the guide, the cable being fastened to a plate mounted on the pin. Normally, the push-roller can pass through a slot in the carriage; but, when a launch is to be made, the slot is closed by a shutter with which the push-roller then contacts. The carriage may be held stationary when the shutter is raised by a brake engaging one of the rollers and connected by a chain to the shutter. The buffer stop comprises a box-shaped structure fitted with adjustable gripping plates and buffers. A spring-controlled stop piece may be fitted to the deck or the stop to limit rebound of the carriage.

115,466. L. C. Ford, 1e, Ordnance Road, St. John's Wood, London. May 5, 1917.

Girders, etc., Aircraft.—Girders, beams, spars, ribs, and other rigid structural members are formed from tubes or other hollow bodies by cutting and bending certain portions so that box girders with cross braces or ties are produced. Such girders are applicable for the frames of the wings of aircraft. The girder is formed by cutting a tube and bending the cut portions. The cuts for the diagonals on opposite sides are inclined in opposite directions. The flanges of opposite vertical members may abut or be overlapped and secured together. Bent portions constitute flanges for the booms and may be beaded, flanged, or fluted, or be folded to form tubular booms. Diagonal ties are bent from the top and bottom walls of the tube. In a modification the flanges are omitted, and the tube is strengthened transversely by strips bent from the diagonals and secured to the opposite diagonals and cross braces. Two or more tubes may be connected, by means of the bent portions which may be flat or convex in cross section, and the remaining walls of the tubes may be bent to form a triangular section. In another modification, one tube is secured inside the other tube by means of bent portions and the top and bottom walls may be similarly connected. The tubular blanks may be rectangular, or circular, triangular, or stream-line in section; the shape of the cross section may vary along the length, and the tubes may be twisted or bent longitudinally and be closed at one or both ends. Sheet metal blanks may be cut, stamped, and fluted, and then be formed into tubes or other hollow bodies having the cross braces described above.

115,480. R. F. Wells, 30, Whitehead's Grove, Chelsea, London. May 8, 1917.

Ways and Guides, Aerial.—An aerial railway comprises a suspended track wire, on which runs a torpedo-shaped car provided with an aerial propeller and with lifting planes and steadying pins. A car is fitted with planes, a propeller and fins, the fins having each three or more rollers engaging a track wire. The track wire is suspended from cross spans or beams carried on vertical posts placed to one or both sides of the track and may be tight or allowed to hang in loops. Where rivers are crossed the wire may be supported by an additional catenary wire. Power may be supplied through a separate electric conductor parallel to the track. Floating supports may be used when lakes are traversed. Specification 17859/93 is referred to.

AERONAUTICAL INVENTIONS.

The Air Ministry wishes it to be known that the Air Inventions Committee, which was formed about nine months ago, has now received and examined upwards of 5,000 inventions and suggestions relating to the Air Service.

It is regretted that, owing to war conditions, a detailed account of their investigations cannot be published, but the experience of the Committee indicates that it may be possible to publish certain information which will facilitate the work both of the inventors and of the Committee.

The following statement has been drawn up with this object in view, but it is realised that it is incomplete for the reason just given. It is appreciated also that inventors are placed at great disadvantages in present circumstances, for, unless immediately connected either with the Air Services or with aircraft manufacture it is almost impossible that they should be acquainted with the most recent developments; so rapid has been the recent rate of progress that it is difficult, even for those in close contact with the Royal Air Force, to keep abreast of all the latest improvements. Again, it is practically useless for inventors at the present time to submit inventions which would necessarily take a long time to develop, the requirements of war and the conditions of labour and material making it impossible for the Committee to support proposals of this nature.

Generally speaking, and as far as the period of the war is concerned, no very startling change in the present type of aircraft is anticipated, although improvements in parts and also in details are always possible and may produce very important results.

The stage of development in construction which has now been reached is such that major improvements can only be expected from those possessing the requisite scientific and mechanical knowledge, skill and experience. Thus, radical changes in the shape of the wings of aeroplane, the body, and the propellers are only possible after long and patient research carried out in aeronautical laboratories.

Again, many inventors have forwarded proposals for helicopters and aircraft of this nature which, if an efficient design can be produced, would possess certain advantages (but probably not so great as was once imagined); others have suggested flapping wings and rotatory planes. Such schemes do not give any promise of being developed for use during this war, and in any case would require some years of experiment before they could be regarded as practical proposals.

As regards minor improvements, inventors should bear in mind that many details, such as turnbuckles, clips, etc., are now standardised, and a change would only be justified by some very marked superiority.

Safety devices for preventing crashing of the machine and the pilot form a numerous class. The chief of these is the parachute, either applied by a harness to the pilot or directly attached to the machine. Those who have seen a passenger dropped by a parachute from an aeroplane for exhibition purposes often fail to realise the conditions under which a parachute may have to be used as a safety appliance. Then the machine may be out of control, dropping at a velocity of 150 to 200 miles per hour, or spinning downwards in flames. Many other safety devices, such as automatic stabilisers, wind brakes, etc., have been proposed at various times. The additional weight entailed by the use of any of the suggested safety appliances must remain a very serious factor for so long as war conditions prevail.

The engine is the heart of the aeroplane, and on its reliability depends the safety of the pilot. Persons acquainted only with motor car engine practice sometimes do not realise the exacting conditions under which an aeroplane engine must work. The engine must be capable of running for the whole of the time of flight at its maximum power. The lubrication and ignition must be perfect, and the engine must not become overheated. The rating applied to aeroplane engines is its weight per horse-power, and engines are now being produced which show surprising results in this respect. Inventions which differ radically from present day practice (such as the internal combustion turbine) have small possibilities of being adopted, for successive design and reconstruction entailing probably several years' work are necessary before satisfactory results can be hoped for. In view of the shortages of materials and labour at the present time no new type can be embarked on unless it is demonstrably superior to existing types and possessed of definite and immediate advantages over them.

A subject which is intimately connected with the power plant is its noise. This constitutes one of the disadvantages of an aeroplane. For night flying a method by which it would be possible to hear from one aeroplane, the approach of another, would be of great advantage. The engine can be silenced without serious disadvantages, but the noise of the propeller and the hum of the wires are so great that silencing the engine is not sufficient.

Many proposals for the projection of bombs and grenades of flame and of poisonous gases have been received.

The trailing bomb or grapnel for attacking enemy aircraft and submarines is a favourite suggestion from inventors. This device was tested before the war and at various times since, but has been abandoned in favour of more effective methods.

Instruments.

Many hundred of inventions and suggestions for inclinometers and instruments for straight flying and accurate bomb-dropping have been investigated. Efficient and well designed instruments for these purposes have been available for some time past, but it is quite possible that improved forms may be produced, though it is scarcely likely that this can be done by anyone who does not possess the necessary scientific and mechanical knowledge required for an investigation of this nature.

Some inventors entirely disregard the action of centrifugal force upon pendulum and spirit level devices.

A large number of gyroscopic instruments have been proposed which show insufficient knowledge of the correct application and limitations of a gyroscope.

Anti-aircraft devices of various kinds are constantly suggested, but now contain very little new matter for consideration as such proposals have received the careful attention of the authorities for a long time past and have been the subject of much trial and experiment.

Any proposals of a practical nature which contain features of novelty and may be of utility are discussed with the assistance of the Air Service.

The Committee fully appreciate the genuinely patriotic motives which inspire most of the communications which they have received, and it is with the object of encouraging the submission of useful and well-considered proposals that this statement is issued. Inventors should, however, bear in mind that the somewhat obvious proposals which might have been useful in an earlier stage of the war, are now no longer serviceable.

By following the general tenour of the above suggestions, inventors will greatly assist the Committee in the execution of their responsible duties.